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Chemistry - Separation Processes  
for Plutonium and Uranium

AEC Research and Development Report

DISSOLVER FOR  
NATURAL URANIUM FUEL ELEMENTS

by

V. P. Caracciolo

Separations Engineering Division

December 1958

MASTER

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CHEMISTRY-SEPARATION PROCESSES  
FOR PLUTONIUM AND URANIUM  
(TID-4500, 14th Ed.)

DISSOLVER FOR  
NATURAL URANIUM FUEL ELEMENTS

by

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### ABSTRACT

Sufficient data were obtained with a semiworks-scale dissolver to permit design of plant-scale equipment for the dejacketing and subsequent dissolving of aluminum-clad uranium fuel elements of various shapes and sizes. The aluminum dejacketing reaction occurred as fast as caustic was added and was independent of the shape of the elements. The rate of uranium dissolving increased with increasing acidity, was proportional to the exposed surface area, and was independent of the shape of the elements. A mechanism for uranium dissolution is discussed that explains the variation of acid consumption and the rate of gas evolution.

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# DISSOLVER FOR NATURAL URANIUM FUEL ELEMENTS

## INTRODUCTION

The first step in the chemical separation of the plutonium, uranium, and fission products in natural uranium fuel elements is the preparation of an aqueous solution of the elements in nitric acid. For aluminum-jacketed elements, the jacket is first removed with caustic and the uranium is then dissolved in nitric acid.

Satisfactory performance had been obtained in plant-scale equipment when processing short cylindrical elements. However, since longer elements of various shapes may be advantageous from the viewpoint of reactor technology, it was desirable to study their dissolution. This study was made on a semiworks scale to provide data for the design of plant-scale equipment with sufficient flexibility to handle a variety of types of elements.

## SUMMARY AND CONCLUSIONS

A semiworks-scale dissolver was used to obtain sufficient data to permit design of plant-scale equipment for dejacketing and dissolving natural uranium elements of various shapes and lengths.

Three shapes were studied: solid and hollow cylindrical slugs approximately 8-1/2 inches in length, and flat plates 2-1/2 feet in length. No difficulties were noted in the dejacketing of either bundled flat plates or the inner jacket of the hollow slugs. After a short induction period the removal of aluminum was very rapid and was controlled by the rate of caustic addition.

The dissolution rate of the uranium increased with increasing acidity and was proportional to the exposed surface area. The dissolution rate of the flat plates was increased by controlling the dejacketing so that the aluminum ribs remained to provide better spacing between the plates, thereby increasing the effective surface area.

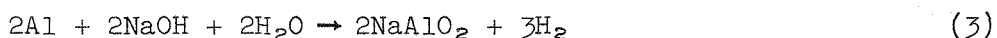
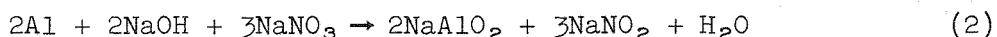
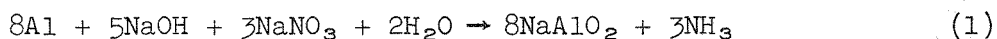
A mechanism for uranium dissolution is presented that qualitatively explains the initial peak observed in the rate of gas evolution and the variation in acid consumption.

A reduction of 50% in the off-gas peak that occurred during the first half-hour of dissolution was obtained by injecting steam into the off-gas condenser to purge out air and provide condensate to absorb NO<sub>2</sub>.

## DISCUSSION

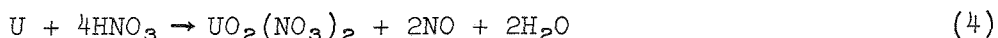
### CHEMISTRY OF THE PROCESS<sup>(1,2)</sup>

The aluminum jacket that covers the uranium is removed by a boiling aqueous solution of NaOH and NaNO<sub>3</sub>. The fuel elements are immersed in the dissolver and the caustic is added at a controlled rate to the boiling sodium nitrate solution. The NaNO<sub>3</sub> serves to suppress the formation of hydrogen gas by causing the reaction to proceed according to reactions (1) and (2) instead of reaction (3).

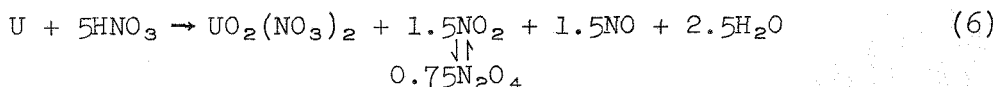


A ratio of at least 1.65 mols of NaOH in the initial solution to one mol of aluminum to be dissolved is required to ensure complete dejacketing and to prevent the precipitation of NaAlO<sub>2</sub> complexes. A NaNO<sub>3</sub> concentration of about 20 weight per cent is sufficient to suppress hydrogen evolution such that a minimum of air inleakage is required to keep the concentration of hydrogen in the off-gas below the lower explosive limit.

After completion of dejacketing, the uranium metal is dissolved with 50 weight per cent HNO<sub>3</sub> (10.4N). Due to the complexity of the reaction, no single equation can be written to represent the dissolving reaction. The following equations represent reactions which are probably involved.



Although the exact mechanism is not known, the following empirical equation fits the observed behavior fairly well.



### EXPERIMENTAL EQUIPMENT

The dissolver (see Figure 1) was a stainless steel box equipped with heating and cooling coils. The fuel elements were placed in a stainless steel loading rack (Figure 2) in order to allow easy removal of the heel for inspection and weighing at the end of a run. The reflux condenser was a shell-and-tube, up-draft type having 60 square feet of cooling surface (Figure 3). A steam jet was used to remove the off-gases. A piping diagram of the equipment is given in Figure 4. Water seals were provided for both the dissolver and condenser to



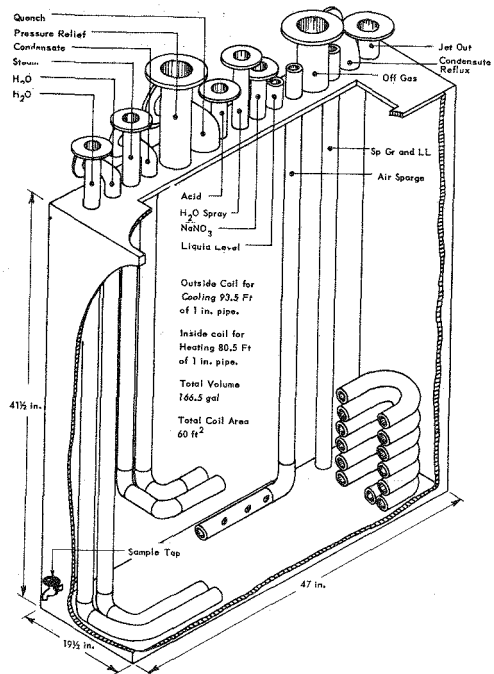


FIGURE 1 - DISSOLVER

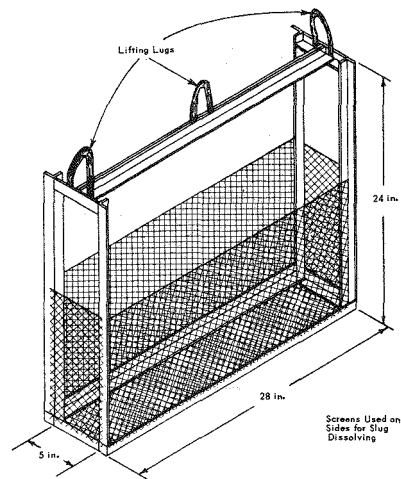


FIGURE 2 - LOADING RACK

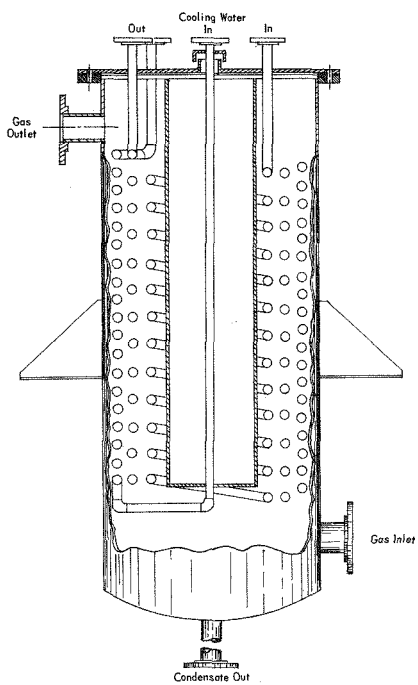


FIGURE 3 - SEMIWORKS UP-DRAFT CONDENSER

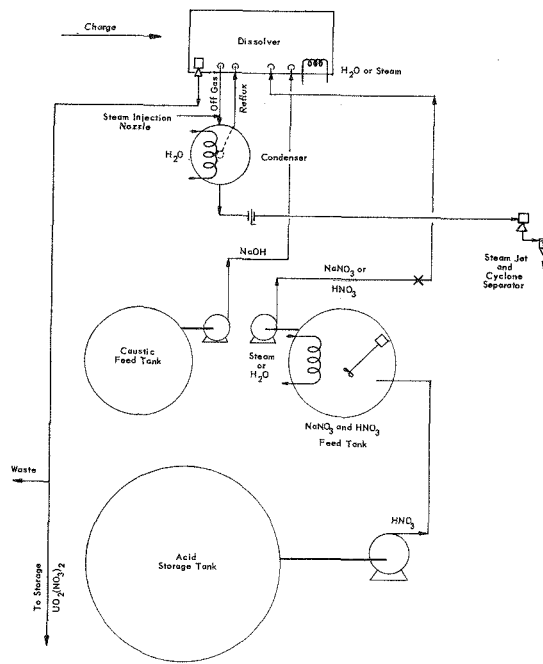


FIGURE 4 - SEMIWORKS DISSOLVER FLOW DIAGRAM

prevent accidental overpressuring. A quick-opening quench valve was provided to flood the dissolver with water in case the reaction proceeded too rapidly.

## EXPERIMENTAL PROCEDURE

### DISSOLVER CHARGING

Three types of elements were dissolved: flat plates, hollow slugs, and solid slugs. Descriptions of these elements are given in Table I, and an isometric drawing of the elements is shown in Figure 5.

TABLE I

Description of Natural Uranium Elements

<u>Element Description</u>	<u>Bonding Agent</u>	<u>Pounds of Aluminum per lb of Uranium</u>	<u>Surface Area, in<sup>2</sup>/lb of Uranium</u>	<u>Surface Area Ratio*</u>
Standard Al-Si bonded solid slugs	Al-Si	0.0338	6.26	1
Flat plates	Ni	0.067	16.0	2.55
Hollow slug	Al-Si	0.0514	10.5	1.68
Hollow slug	Ni	0.0478	10.6	1.68

\* Surface Area Ratio =  $\frac{\text{surface area /lb U for new fuel element}}{\text{surface area /lb U for standard slug}}$

A typical charge consisted of 300 pounds of flat plates, 2-1/2 feet in length, arranged in six bundles of five plates each stacked two abreast and three high. This was added to 100 pounds of uranium which had been partially dissolved in a previous cycle. A typical view of a charge ready for dissolving is shown in Figure 6. The bundles were bound with iron wires to facilitate loading. These wires dissolved with the uranium. A 180-pound weight (Figure 6) was placed on top of the charge to simulate the crushing effect on the bottom plates of a larger dissolver charge.

When solid or hollow slugs were dissolved, the rack was converted into a basket by enclosing it within stainless steel wire mesh. The slugs were dumped randomly into the basket. A typical charge of 300 pounds of hollow slugs is shown in Figure 7.

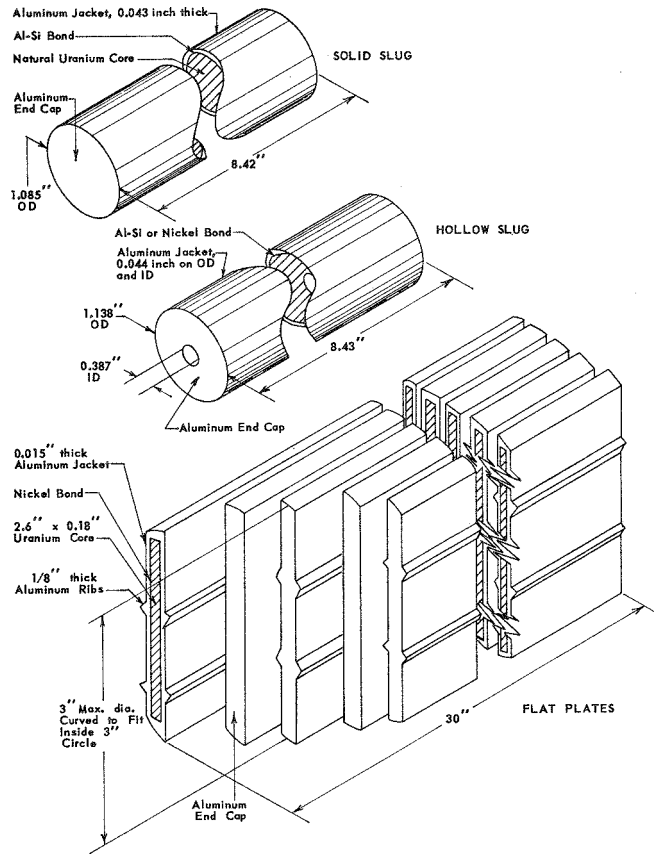


FIGURE 5 - ISOMETRIC PROJECTION OF FUEL ELEMENTS

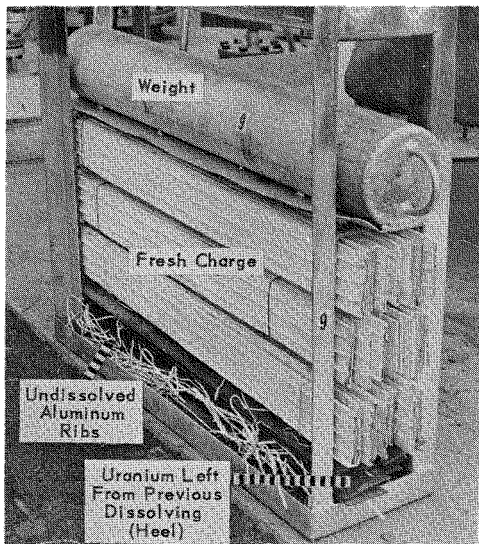


FIGURE 6 - TYPICAL CHARGE OF FLAT PLATE ELEMENTS

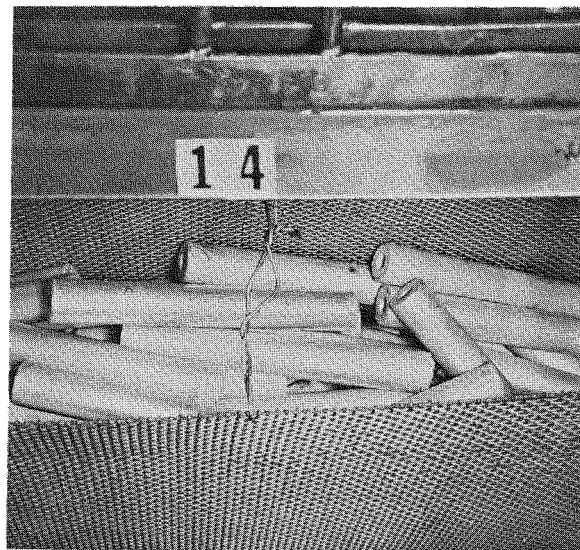


FIGURE 7 - TYPICAL CHARGE OF HOLLOW SLUGS

## DEJACKETING

Sufficient 20% NaNO<sub>3</sub> was added to the dissolver to give a ratio of 2-1/2 mols of NaNO<sub>3</sub> to one of aluminum and was then heated to the boiling point. The steam was shut off and the required amount of 25% NaOH was added over a period of 40 minutes. The dissolver was held at 5 inches water vacuum during both dejacketing and dissolution steps. The dejacketing step was terminated when the temperature rise of the condenser cooling water returned to zero, indicating that the reaction was complete.

## URANIUM DISSOLUTION

The uranium was dissolved by adding the required volume of 50% HNO<sub>3</sub>(10.4N) to the dissolver and heating to maintain the solution at the boiling point. Even though the dissolution reaction was exothermic, external heat was required to initiate the reaction and to supply the heat absorbed by the endothermic side reactions. Freeboard about equal to the depth of solution was required to prevent foam from plugging the off-gas system. The reaction was stopped when the acid concentration reached 1% (0.15N).

## EXPERIMENTAL RESULTS

### DEJACKETING

One hour was required for dejacketing independent of the shape of the elements (Table II).

TABLE II

Summary of Dejacketing

Initial NaNO<sub>3</sub> concentration - 20 wt %  
Initial NaOH concentration - 25 wt %  
Caustic addition time ≤ 40 minutes  
Dejacketing temperature - 103°C

<u>Fuel Element</u>	<u>Mols of NaOH added per mol of Al</u>	<u>Mols of NaNO<sub>3</sub> added per mol of Al</u>	<u>Description of Elements After Dejacketing</u>	<u>Time for Completion of Reaction from Start of Caustic Addition, min</u>
Solid slugs	2.7	2.9	Al end caps and Al-Si bond remained	46
Flat plates	2.8	2.2	All Al removed Ni bond remained	60
Hollow slugs having Al-Si bonding	2.4	2.2	All Al removed Al-Si bond remained	65
Hollow slugs having Ni bonding	2.3	2.2	Al end caps and Ni bond remained	55

Additional time was required to ensure complete dissolution of the end caps and fittings. However, the additional time was not essential since the small amount of aluminum that remained dissolved during subsequent dejacketings.

The bonding agent (Al-Si or nickel) was not removed during the dejacketing. A photograph of solid slugs after dejacketing is shown in Figure 8. The dejacketing of both the solid and hollow slugs was terminated when the temperature rise of the condenser cooling water returned to zero, indicating that the reaction was complete.

A time cycle was established in which the aluminum ribs on the flat plate elements were not removed. These ribs on the plates maintained a spacing between plates during dissolving of the uranium and prevented any reduction in the effective surface area. Control of the time cycle was demonstrated to be practical. Since the heat evolved by the reaction after removal of the major part of the aluminum surface decreased by a factor of four over a five-minute period, the end point of partial dejacketing was determined by the sharp drop in the exit temperature of the condenser cooling water. When the  $\Delta t$  of the condenser cooling water had decreased to 50% of its maximum the dissolver was cooled by circulating water through its coils. Approximately 30 minutes were required for this partial dejacketing.

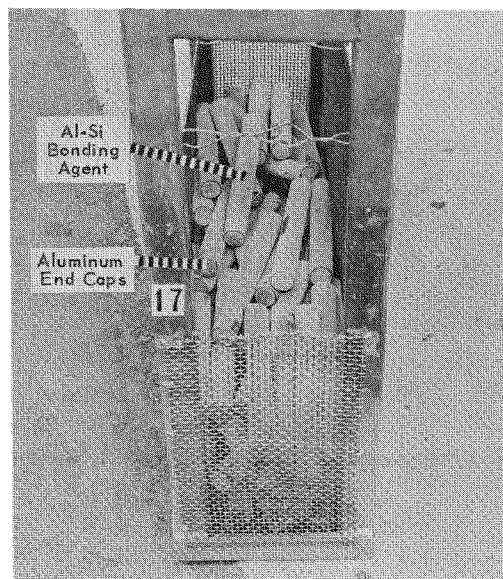


FIGURE 8 - SOLID SLUG CHARGE AFTER DEJACKETING

Complete dejacketing required approximately one hour at which time the temperature rise of the condenser cooling water returned to zero. Photographs of flat plates after dejacketing are shown in Figures 9 and 10.

The condenser heat load during dejacketing went through a sharp peak as shown in Figure 11. The peak load was a direct function of the rate of addition of caustic and the area of the aluminum surface.

The effects of caustic and  $\text{NaNO}_3$  concentration on the rates of reaction and hydrogen evolution were not investigated since such information was available from other sources.<sup>(1)</sup>

### URANIUM DISSOLUTION

The reaction rate (pounds dissolved per hour) was proportional to the exposed surface area and independent of the shape of the element Table III, page 14. Charging the flat plates on edge and using partial dejacketing gave maximum utilization of the available surface area (Table III). The use of the weight to simulate the crushing effect of a larger flat plate charge had no significant effect on the reaction rate. As the core of the hollow slugs was readily attacked, the reaction surface area was proportionally larger than that available with solid slugs.



FIGURE 9 - CHARGE OF FLAT PLATES AFTER PARTIAL DEJACKETING

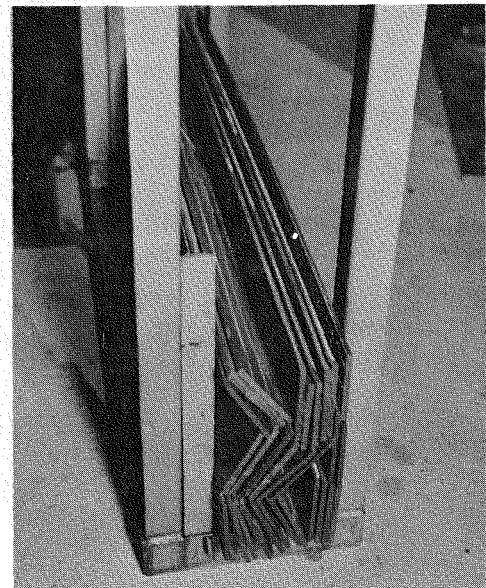


FIGURE 10 - CHARGE OF FLAT PLATES AFTER COMPLETE DEJACKETING

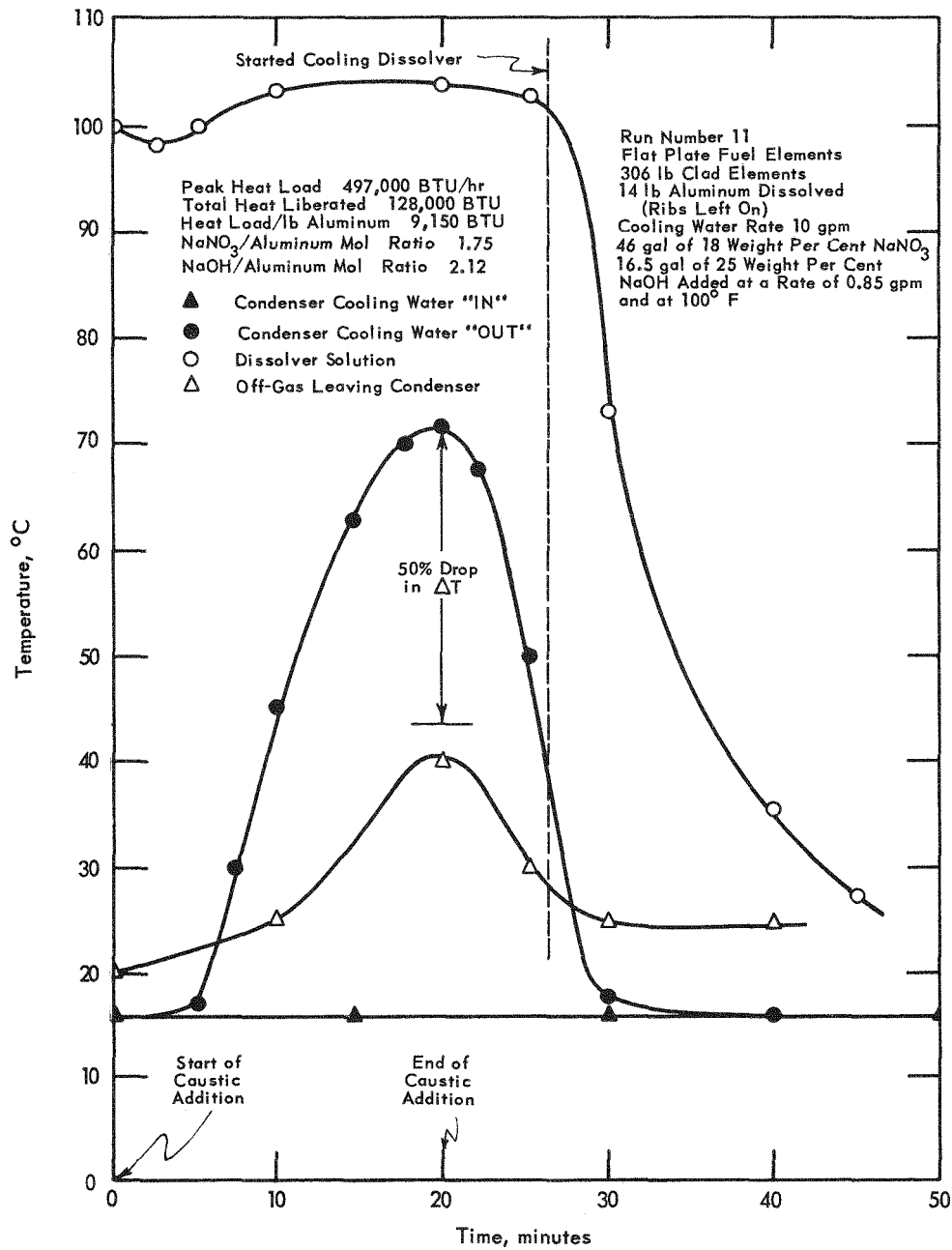


FIGURE 11 - VARIATION OF TEMPERATURE DURING DEJACKETING

TABLE III

Comparison of the Dissolution Rates for the Various Fuel Elements<sup>(1)</sup>

Fuel Element	Surface Area Ratio	Uranium Dissolution Rate, lb per hr			U Dissolution Rate for New Elements, lb/(hr)(ft <sup>2</sup> )
		U Charged, 300 lb New Elements	U Charged, 200 lb New Elements	U Charged, 300 lb Residue	
Solid slugs	1	5.77	7.85 <sup>(3)</sup>	5.03 <sup>(4)</sup>	0.442
Hollow slugs	1.68	8.72 <sup>(2)</sup>	13.2 <sup>(3)</sup>	19.5	0.400
Flat plates	2.55				
Partial dejacketing		14.0	20.0	21.7	0.42
Complete dejacketing		9.0	-	-	0.27

- (1) All runs were made at a temperature of 105°C using an initial HNO<sub>3</sub> concentration of 50% (10.4N) and dissolving 1/3 to 1/2 of the charge. Final acid concentration 1% (0.15N).
- (2) Average value. The rates obtained for the Al-Si bonded and the Ni-bonded types were 9.57 lb/hr and 7.82 lb/hr, respectively.
- (3) Calculated rate based on surface area ratio and assuming equal pitting during attack.
- (4) Rate low because surface area decreases rapidly for solid slugs as uranium dissolves.

The reaction rate decreased with decreased initial acid concentration (Table IV) and was unaffected by the addition of air to the dissolver (Table V).

TABLE IV

Effect of Initial Acid Concentration on Uranium Dissolution Rate

Flat Plate Fuel Elements Average Dissolution Temperature, 105°C						
Acid Concentration, N		Uranium Charged			U Dissolved, lb	Average Dissolution Rate, lb/hr <sup>(1)</sup>
Initial	Final	Residue, lb	New Elements, lb	Total, lb		
10.3	1.1	89	281	370	181	23 <sup>(2)</sup>
6.44	0.14	85	299	384	180	14.4

- (1) Based on a total charge of 400 pounds of uranium.
- (2) Based on extrapolation to a final acid concentration of 0.15N.

TABLE V

Effect of Air Leakage on Uranium Dissolution Rate

Flat Plate Fuel Elements Average Dissolution Temperature, 105°C							
Air Leakage Rate, ft <sup>3</sup> /min (STP)	Acid Concentration, N		Uranium Charged			U Dissolved, lb	Average Dissolution Rate, lb/hr <sup>(1)</sup>
	Initial	Final	Residue, lb	New Elements, lb	Total, lb		
nil	10.4	0.14	95	283	378	211	24
1.86	10.3	1.1	89	281	370	182	23 <sup>(2)</sup>

- (1) Based on a total charge of 400 pounds of uranium.
- (2) Based on extrapolation to a final acid concentration of 0.15N.



The presence of residual uranium or "heel", from a previous dissolving increased the dissolution rate. This increase in rate was attributed to the additional surface area of the heel. Table VI summarizes the results obtained with flat plates. Photographs of the elements after the first cut of the dissolution are shown in Figures 12 and 13.

TABLE VI

Effect of Residue from Previous Dissolving on the  
Dissolution Rate

Flat Plate Fuel Elements Average Dissolution Temperature, 105°C					
Uranium Charged			Acid Concentration, N		Apparent Dissolution Rate, lb/ hr <sup>(1)</sup>
U Residue, % of Total U Charged	New Elements, % of Total U Charged	Total Charged, lb	Initial	Final	
0	100	300	10.3	0.15	14.7
24	76	370	10.3	1.1	23 <sup>(2)</sup>
56	44	356	10.3	0.15	34

(1) Based on a total charge of 400 pounds of uranium and dissolving 50% of the total uranium charged.

(2) Based on extrapolation to a final acid concentration of 0.15N.

The acid that was consumed per mol of uranium dissolved was not constant during the dissolution and was dependent upon the amount of air that leaked in. The addition of air to the dissolver decreased the HNO<sub>3</sub> consumed, per mol of uranium dissolved, by oxidizing the NO (reaction 11, p 18) to NO<sub>2</sub> which was then converted to HNO<sub>3</sub> by reaction with water in the condenser. The HNO<sub>3</sub> returned to the dissolver for reuse (Table VII). Additional air above 1.86 cfm, STP, (0.61 mol O<sub>2</sub>/mol of uranium dissolved) had very little effect on acid consumption. The average mols of HNO<sub>3</sub> consumed per mol of uranium dissolved when air inleakage was reduced to a minimum was 4.5.

TABLE VII

Effect of Air Leakage on Mols of Acid Consumed per  
Mol of Uranium Dissolved

Flat Plate Fuel Elements Average Dissolution Temperature, 105°C				
Acid Concentration, N	Leakage Rate,	Mols of O <sub>2</sub> /mol	Acid Consumption, Mols of	
Initial	Final	cfm (STP)	of U Dissolved <sup>(1)</sup>	acid/mol of U Dissolved
10.4	0	nil	nil	5.10
10.3	1.1	1.86 <sup>(3)</sup>	0.606	3.9 <sup>(2)</sup>
6.44	0.14	2.33 <sup>(3)</sup>	1.35	3.84
6.54	0.1	2.3 <sup>(4)</sup>	1.2	3.5

(1) Theoretical amount of O<sub>2</sub> required to oxidize all the NO to NO<sub>2</sub> is 1.5 mols per mol of uranium dissolved.

(2) Corrected to a final acid of 0.14N, value obtained at final acid of 1.1N runs was 4.0.

(3) Air leakage above the liquid.

(4) Air sparge below the liquid.

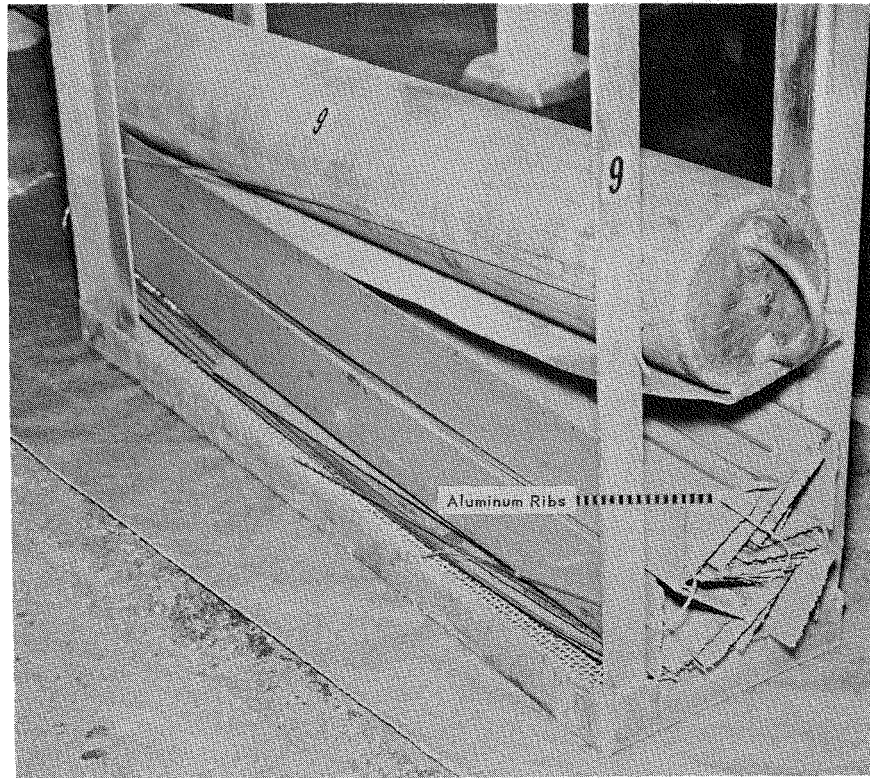


FIGURE 12 - HEEL OF FLAT PLATES AFTER ACID ATTACK

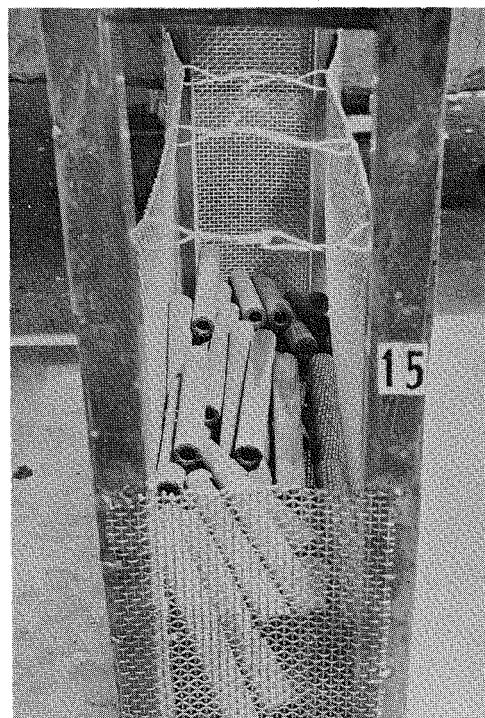


FIGURE 13 - HEEL OF HOLLOW SLUGS AFTER ACID ATTACK

Typical dissolver operating characteristics for 50 and 34% initial acid concentration are shown in Figures 14 and 15.

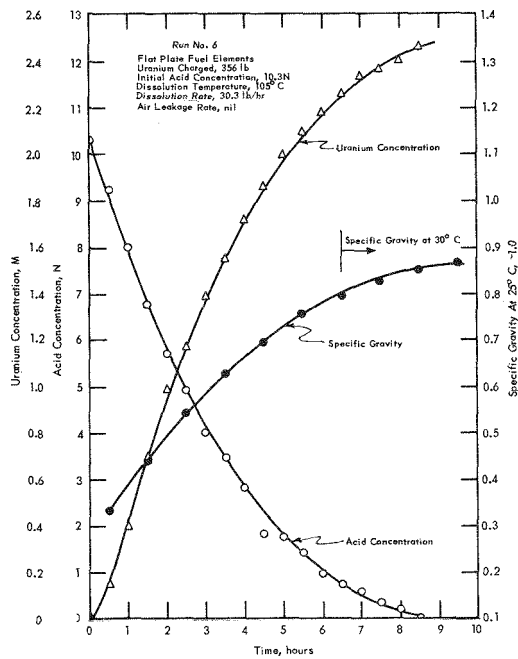


FIGURE 14 - DISSOLVER OPERATING CHARACTERISTICS WITH 50% INITIAL ACID

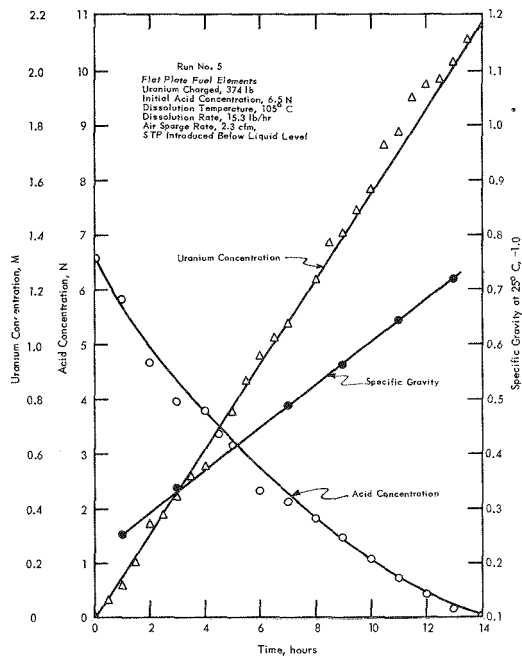
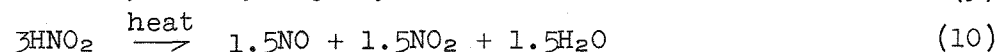
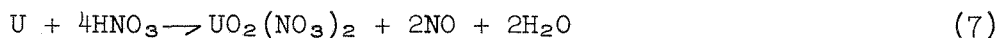


FIGURE 15 - DISSOLVER OPERATING CHARACTERISTICS WITH 34% INITIAL ACID

## PROPOSED MECHANISM OF URANIUM DISSOLUTION

The dissolution of uranium can be considered to pass through three phases. In Phase I the acid concentration is high and the dissolver is below the boiling point; 8 mols of  $\text{HNO}_3$  are consumed per mol of uranium dissolved and the off-gas rate passes through a sharp peak. During Phase II the dissolver begins to boil and acid concentration is still high ( $> 25\%$ ). During Phase III the acid is steadily consumed until it reaches the concentration chosen for the end point; the acid consumption per mol of uranium dissolved depends on the amount of air that enters the dissolver. The reactions that are involved are:



### Phase I

#### Initial Phase of Uranium Dissolution

Conditions: High acid concentration ( $> 45\%$ ).

Free volume of dissolver filled with air.

Solution below boiling point and no reflux coming from the condenser.

According to reactions (7) and (8), 8 mols of acid are consumed per mol of uranium that is dissolved, Figure 16. Reaction (8) is known to occur rapidly in the presence of high acid, but becomes slow below an acid concentration of about 25%. The combined effects of air in the dissolver vapor space and large volumes of gas produced by reaction (8) result in a sharp peak in the off-gas rate, Figure 17. The off-gas peak occurs between 80 and 95°C and the rate decreases rapidly as the boiling point is reached.

### Phase II

#### Intermediate Phase of Uranium Dissolution

Conditions: Medium acid concentration (25 to 45%).

Dissolver at boiling point and condensate being returned to dissolver.

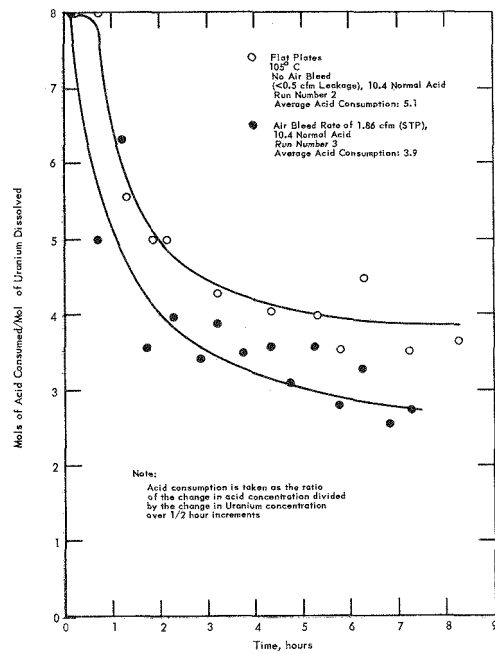


FIGURE 16 - ACID CONSUMPTION DURING DISSOLUTION

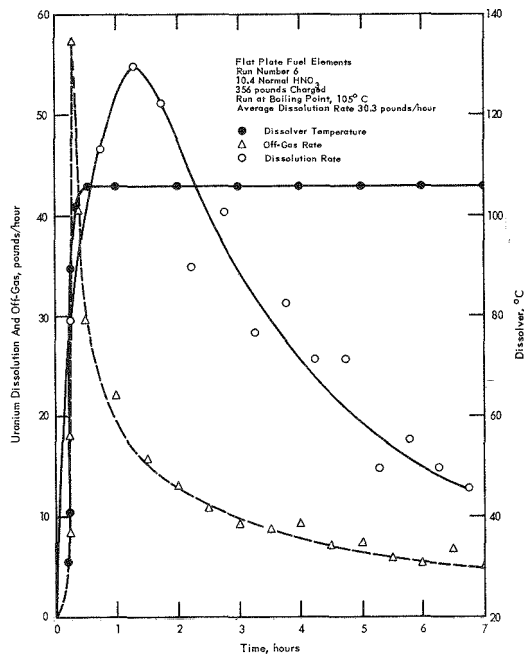


FIGURE 17 - DISSOLUTION AND OFF-GAS RATES VS. TIME

Reaction (7) continues at a high rate during this period; reaction (8) starts to decrease as the acid concentration decreases, so that the acid consumption per mol of uranium gradually decreases, as shown in Figure 16. In addition, some of the  $\text{NO}_2$  and  $\text{N}_2\text{O}_4$  react with  $\text{H}_2\text{O}$  in the condenser, according to reaction (9), and return to the dissolver as  $\text{HNO}_3$ . The  $\text{HNO}_2$  formed by reaction (9) decomposes at the temperature of the condenser, according to reaction (10), so that only about 50% of the nitrogen oxides are recovered. This destruction of  $\text{HNO}_2$  was verified by analysis of the condensate return, which had a high  $\text{HNO}_3$  acidity but only a trace of  $\text{HNO}_2$ . The uranium dissolution rate goes through a maximum during this phase when using a 50% initial acid concentration as shown in Figure 17. No peak was observed when the initial acid concentration was decreased to 34%. Although the exact cause is not known, the peak is believed caused by the combined effects of reactions (7) and (8) competing for the acid, and increased surface area caused by pitting, resulting in a rapid decrease in acid concentration and a corresponding decrease in dissolution rate.

### Phase III

#### A. Final Phase of Uranium Dissolution Without $\text{O}_2$ Present

Condition: Low acid concentration (< 25%).

Reaction (7) is proceeding at a lower rate and, since the acid concentration is low, the  $\text{NO}$  does not react with acid and goes to the off-gas. No  $\text{O}_2$  is present to oxidize it to  $\text{NO}_2$  which could then be recovered by reaction (9). The result is an acid consumption of 4 mols per mol of uranium, as given in Figure 16.

#### B. Final Phase of Uranium Dissolution with $\text{O}_2$ Present

Condition: Low acid concentration (< 25%).

Reactions (9), (10), and (11) continue and all the  $\text{NO}$  is recovered as nitric acid. The result is that 2 mols of acid are recovered per mol of uranium dissolved, so that the net acid consumption is 2 mols per mole.

### **REDUCTION OF PEAK OFF-GAS RATE**

In the operation of a dissolver it is desirable to maintain a partial vacuum at all times to prevent the outleakage of radioactive gases. To do this a system must be provided that is capable of handling the peak evolution of gas that occurs at the start of the dissolutions.

From the preceding discussions of dissolution reactions it appeared that there were at least two possible methods of reducing or eliminating this peak:

1. Reduce the initial acid concentration.
2. Inject steam into the vapor space of the dissolver before the dissolver reaches the boiling point to purge out the air and to provide water vapor to convert the  $\text{NO}_2$  to  $\text{HNO}_3$ .

Method 1 would reduce the peak off-gas but would also increase the over-all dissolution time by slowing down the reaction. This would greatly reduce the capacity of the dissolver. Method 2 offered an easy method for minimizing the peak without sacrificing dissolver capacity.

The peak off-gas rate was reduced 30 to 50% by injecting steam into the condenser to react with the  $\text{NO}_2$ . When the dissolver temperature reached  $50^\circ\text{C}$ , steam was injected at a rate of 90 pounds per hour until the solution in the dissolver began to boil. Figure 18 is a plot of the peak off-gas rate with and without the use of steam injection.

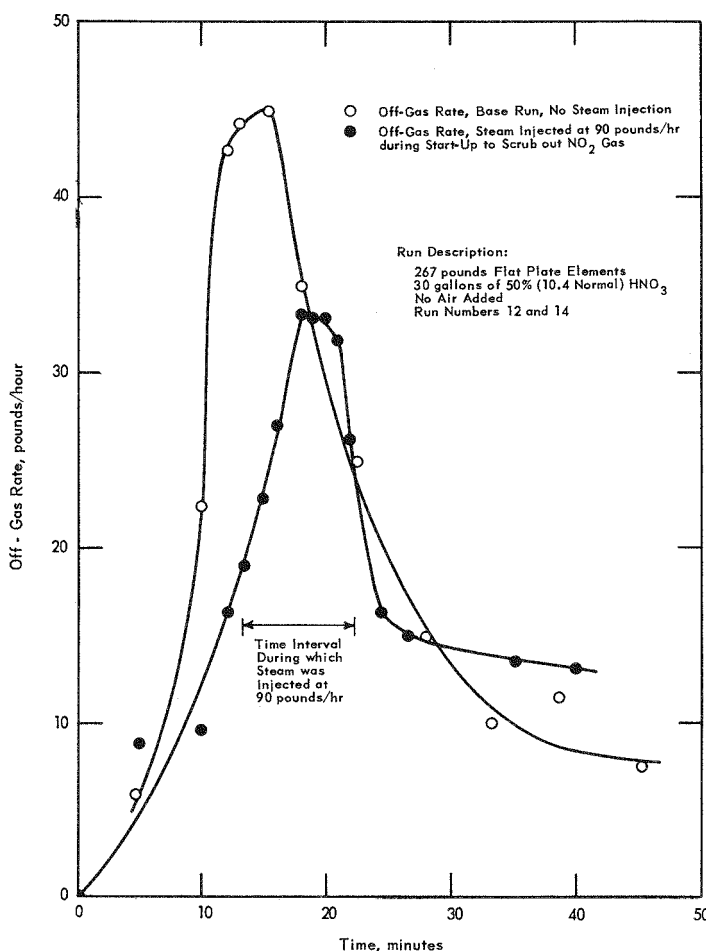


FIGURE 18 - PEAK OFF-GAS RATE WITH AND WITHOUT STEAM INJECTION

The results of this experiment confirms laboratory data on methods of reducing the peak. The laboratory results will be discussed in a forthcoming DP report by C. S. Schlea. An additional reduction in off-gas might be achieved by starting steam injection at even a lower temperature to purge out the air. This was not done in the semiworks dissolver because of the possibility of diluting the small volumes of acid used.

Another method of reducing the off-gas peak, limiting the immersion of the uranium during start up, was rejected because of fear of explosive reactions.

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APPENDIX

DISSOLVER STUDIES

SUMMARY OF RUNS

Run Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
I. <u>Charged Description:</u>	Type Element	Solid Slugs	Flat Plates	Flat Plates	Flat Plates	Flat Plates	Flat Plates	Flat Plates	Hollow Slugs, Al-S1 Bonded	Hollow Slugs, Ni Bonded	Hollow Slugs	Flat Plates	Flat Plates	Flat Plates	
	U charged, lb	302	285	282	298.5	284	156	none	305	294	none	290	0	0	
	U residue, lb	none	92.5	89.3	86	89.5	200	267.5	none	none	196	143	267	267	
	Total U, lb	302	378.5	371.3	383.5	373.5	356	267.5	305	294	196	433	267	267	
Al charged, lb (estimated)	10	16	16	16	16	10	1	13.5	14	0	16	0	0	0	
II. <u>Dejacketing:</u>	Degree of dejacketing	complete	partial	partial	partial	partial	partial	complete	complete		partial				
	NaNO <sub>3</sub> added, gal	53	50	37	50	48	54	46	50		46				
	NaNO <sub>3</sub> conc., %	19	20	19.5	20.2	20.2	18.2	19	20		17.8				
	Mols NaNO <sub>3</sub> added/mol Al	2.9	1.9	1.42	1.9	1.9	3.0	2.2	2.2		1.75				
	NaOH added, gal	12	21	--	24	20	15	14.5	14		16.5				
	NaOH conc., M	9.0	--	9.1	7.7	8.6	8.4	10.1	10.3		8				
	Mols NaOH added/mol Al	2.7	--	--	2.6	2.4	2.8	2.43	2.3		2.12				
	NaOH addition rate, gpm	0.75	0.9	--	~1	~1	~1	0.4	0.4		0.85				
	Time to dejacket, min from start of NaOH	46	30	30	32	24	30	66	55		30				
	Condenser cooling water, gpm	10	14	10	10	10	10	10	10		10				
	Dissolver vacuum in. H <sub>2</sub> O	4-6	5	5	5	5-7	6	6-8	4-5		5				
	Peak condenser heat load, Btu/hr x 10 <sup>-5</sup>	2.75	--	--	3.51	6.66	3.33	3.6	2.97		5.0				
	Final dejacketing solution:														
	Volume, gal	62	72	49	74	65	69	58	65		69				
	Sp gr at 25°C	1.176	1.246	1.265	1.181	1.210	1.180	1.218	1.183		1.192				
	Al conc., M	0.44	1.05	1.07	0.55	0.54	0.77	1.06	0.83		1.2				
	OH <sup>-</sup> conc., M	3.6	7.5	--	6.5	7.14	4.25	6.9	5.1		5.7				
III. <u>Uranium Dissolution:</u>	Run Conditions														
	Air leakage, cfm (STP)	nil	nil	1.86 <sup>(1)</sup>	2.33 <sup>(1)</sup>	2.30 <sup>(2)</sup>	nil	nil	nil	nil	nil	nil	nil	nil	
	Dissolver vacuum, in. H <sub>2</sub> O	5-6	3-5	5-7	5-6	5	4-6	5-7	3-5	3-6	4-6	5	5	5	
	Condenser cooling water, gpm	10	14-10	10	10	10	10	10	10	10	10	10	10	15 to 10	
	Dissolver steam pressure, psig	5	5	5	5	5	5	5	5	5	5	5	5	5	
	Dissolver temp, °C	105	105	105	105	105	105	105	105	105	105	105	105	105	
	Initial acid conc., N	10.6	10.4	10.3	6.44	6.54	10.3	10.5	10.2	10.5	9.7	9.75	10.2	9.72	
	Acid added, gal	22.5	50	42	55.5	59.5	52	40.5	21.6	24.5	23	33	28	38	
	Steam injected, lb/hr											0	27	90	
	Duration of steam injection, min											0	7	10	
	Run Results														
	Duration of run, hr	18	10	7.5	13	14	9.5	10.5	10.5	13.3	8.75	1	1	1	
	U dissolved, lb	104	214	183.3	179	214.5	242.5	193	101.5	100	113	28	32.5	40.5	
	U residue, lb	198	164.5	188	204.5	159	113.5	74.5	204.5	194	79				
	U residue, % of total U	66	43.6	50	53.3	42.6	32	28	67	66.5	41				
	Average U dissolution, lb/hr	5.8	21.4	24.5	13.8	15.3	25.5	18.4	9.7	7.55	12.75				
	Mols acid consumed/mol U dissolved	4.4	5.1	3.9	3.84	3.5	4.3	4.33	4.1	4.9	3.75				
	Peak condenser heat load, Btu/hr x 10 <sup>-4</sup>	1.8	10.3	8.0	--	--	9.2	8.1	2.65	2.75	5.5	5.9	5.4	10.8	
	Peak off-gas rate, lb/hr	--	--	--	--	--	57.5	55	--	--	--	45	40	33	
	Heat input by steam, Btu x 10 <sup>-5</sup>	3.24	4.55	2.64	--	--	2.72	3.4	1.78	2.86	2.27				
	Heat input by dissolution reaction, Btu x 10 <sup>-5</sup>	1.90	3.98	3.41	3.32	4.0	4.52	3.54	1.90	1.87	2.10				
	Heat removed by condenser, Btu x 10 <sup>-5</sup>	1.64	5.36	4.66	--	--	4.48	4.02	1.32	2.17	1.54				
	Heat input removed by condenser, %	32	63	72	--	--	62	58	36	46	35				
	Start steam injection, min <sup>(3)</sup>											--	14	12	
	Dissolver temp at start of steam injection, °C											--	70	50	
	Reduction in peak off-gas rate, % <sup>(4)</sup>											--	15-20	30-50	
	Product composition:														
	Volume, gal	20	50	39	52.5	50	46.2	36.2	21	19	21				
	Acid conc., N	0.15	0.01	1.1	0.14	0.09	0.01	0.06	0.15	0.15	0.12				
	U conc., M	2.56	2.08	2.37	1.65	2.16	2.52	2.65	2.4	2.22	2.6				
Specific gravity at 25°C	1.876	1.707	1.785	1.595	1.736	1.863	1.86	1.772	1.729	1.844					
			at 29°C			at 30°C	at 30°C								
Average dissolution rate corrected to final acid of 0.15N	5.8	23.5	21.4	13.8	15.3	29	18.8	9.7	7.55	12.75					
Average dissolution rate corrected to final acid of 0.15N, based on 400 lb total charge	7.7	24.8	23	14.4	16.4	32.6	28.1	12.7	10.4	26					

(1) Added above liquid

(2) Added below liquid

(3) From time heat was applied to dissolver

(4) Reduction based on the assumption that off-gas composition was all NO<sub>2</sub> and H<sub>2</sub>O. Reduction is probably higher since the composition of the gas not scrubbed out by steam was of a much lower molecular weight (NO). Also a higher rate of dissolution was obtained which would produce a higher peak than obtained during run number 12.